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APPLICATION OF SPACE TECHNIQUES TO NATURAL RESOURCES STUDY AND ENVIRONMENTAL MONITORING. AN AIRCRAFT EXPERIMENT.

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16. Abstract

The authors describe aircraft and space research designed to better identify ground objects from aerial photographic and spectral acquisition.

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APPLICATION OF SPACE TECHNIQUES TO NATURAL RESOURCES STUDY AND ENVIRONMENTAL MONITORING. AN AIRCRAFT EXPERIMENT.

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This elaboration of methods and means of long distance investigation of terrestrial resources and environmental monitoring is based on complex experiments to study standard objects from aircraft and satellites in conjunction with terrestrial investigation. With the help of specially equipped aircraft laboratories it is possible to carry out a wide range of experiments facilitating the mastery and optimization of methods and equipment for subsequent space surveys as well as the aquisition of actual materials for examining the effectiveness and field of application of long distance probing methods for resolving scientific problems and questions of national economy. /25*

One of these experiments to work out methods and means for long range probing of the terrestrial surface and atmosphere in the visible and near infrared spectral bands was carried out in 1973 by the Institute for Space Research of the USSR Academy of Sciences on the basis of a specially equipped aircraft laboratory. Formulation of the complete on board scientific equipment for the aircraft and of experimental programs was carried out under the following basic assumptions:

1. The selection and processing of space data concerning terrestrial resources and environment should be based on wide application of multi spectral surveys with the aid of completed photographic, scanning and spectral photometric systems.

2. Aircraft surveys make it possible to acquire material for specialists in various fields of science and national economy to work out methods for the thematic interpretation of multi spectral information and optimization of spectral zones for the survey equipment.

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*Numbers in the margin indicate pagination in the foreign text.
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[2]Candidates for Degree in Technological Sciences.

3. Synchronic surveys from aircraft and from space must be carried out with equipment with identical spectral characteristics. A study of the results of joint air and space surveys reveal concrete problems and the fields where /26
use of space equipment versus air vehicles is expedient.

4. The aircraft survey is supported by a limited number of well studied and typical objects distributed in various natural and climatic zones of the country important to identify from ISZ [abbreviation for later inspection] in the interests of science and the realm of the national economy.

5. In order to clarify detection signs of the given objects via spectral amplitude analysis of the results of the multi spectral survey, the surface sectors studied should be photographed many times under different physical and visual conditions and at the characteristic seasonal stages.

6. To study the effects of the atmosphere on the results of multi spectral surveys, the latter must be carried out simultaneously at identical sectors from space, at maximum and minimum height of manned aircraft, and directly on the terrestrial surface.

To meet the stated requirements, the aircraft was equipped with multi spectral photographic scanning and spectral metric equipment with an optical range. Foremost among the scientific equipment developed in the process of experimentation is the multi spectral scanning system based on the model of total selection and mastery of space video recording worked out in the Institute of Space Research. In addition to the multi spectral scanning system (MSS) and the digital video recording on board system, the model elaborated contains a series of earth systems intended to complete various aspects of video data processing and transformation.

The scanning equipment provided on board reception of a representation in four spectral zones 0.35-1.1 combined in space and time and numerically recorded on magnetic tape. Resolution of the representation was done by means of mirror oscillation across the course of flight of the airplaine at a velocity of four sweeps per second. The visual field angle of the scanner was 51°. The data collection of the scanner was deliberately limited to 512 elements per sweep in each spectral channel, on the one hand for imitation of the resolution close to the satellite resolution on the spot, and on the other to facilitate processing the information received on the Universal Electronic Computer.

Distribution of the stream of light in the scanner was handled via a defraction grid, making it possible to change the spectral range in every channel receiving an image. A photo multiplier, selected for its spectral sensitivity, was used as a light collector in the visible field, while silicon photodiodes were used in the near infrared region.

The video signals from the outlets of the light collectors were amplified by direct current amplifiers and transformed into eight digit binary codes. The encoded veal signals were recorded on the magnetic tape of the video storage cipher system, making it possible to maintain the metric nature of the video data.

In order to check the quality of operation of the on board equipment in flight, in addition to the assylographic and cipher methods, an open storage was used to record the image of the photographic surface on electrochemical paper.

The computing unit of the system is designed to research the area of automated interpretational processing of video data received from its spectral amplitude analysis. Color and black and white photo imagery is included in designs for similar research based on magnetic storage of video data in a system for reading ciphered video recordings. As images are reproduced, the photographs are scaled to conform with the altitude and speed /27
of the aircraft. Two basic formats have been adopted to record images: 108 by 300 mm and 54 by 300 mm, with the photo images taken at a height of 500 m being set up in a scale of 1:50,000 and 1:100,000 respectively.

As Edin series EC-1020 electronic computer was used for the numerical processing of the video data. Input and output of video data is handled through a special data preparation system assuring transfer of the magnetic tapes made during the aircraft experiment into the structure and into the mode used in the electronic computer. The video data processed on the computer can later be changed to the initial structure and reproduced as a photo image with the aid of the same data preparation system. The use of the data preparation system eliminates losses in machine time at input and output of information and makes it possible to process video data on any Edin computer series.

The photographic equipment installed on board is a super wide angle, topographic, aerial AFA-TES-5 with two multi spectral synchronized cameras with focal intervals of 100 and 44 mm, making it possible to carry out surveys in six and nine spectral zones, respectively.

For the most part the spectral photometric measurements from aircraft were carried out for the purpose of optimizing the spectral zones. The photometer, scanning for spectra of 42 bands in the visible and near infrared range, and a radiometer, constantly fixing the radiation in four spectral zones from 1.35 to 2.7 μ were used for measurement. The basic characteristics of the on board survey equipment in the field acquisition and resolution phases are shown in Figure 1.

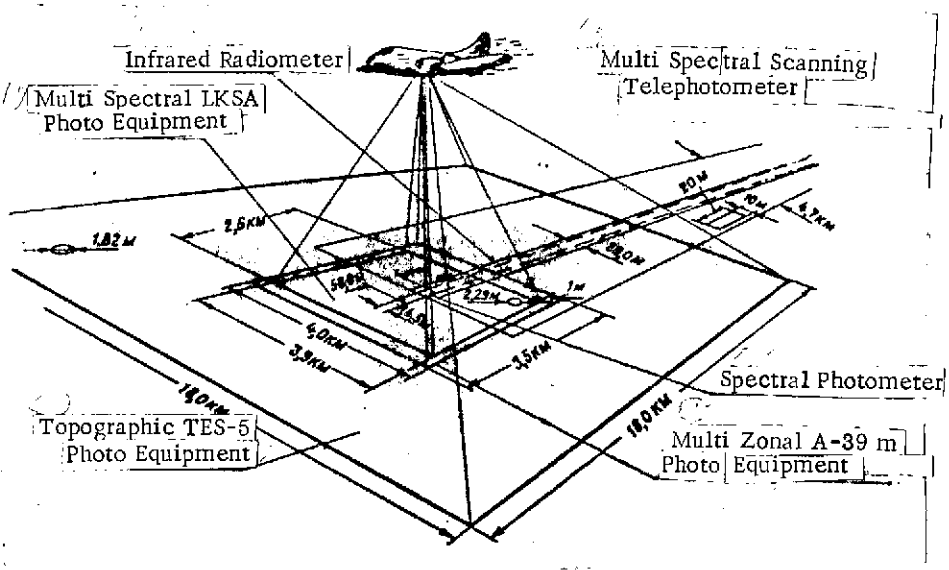

Figure 1. Acquisition and Resolution Made By the Scientific Aircraft Equipment at 5,000 Meters Altitude.

The spectral bands for all types of survey equipment were determined by prior metering of the characteristics of objects photographed and of the effect of the atmosphere on their spectral brightness measured from space. Here it was assumed that natural objects may be divided into classes as a function of spectral brightness. It is relatively easy to select spectral zones in such a way that classes of objects photographed are well differentiated. However, classes of objects which are sharply differentiated by their spectral brightness (forests, meadows, arable land, bodies of water, etc.) are also easy to identify on regular black and white photographs by their integral brightness and, mainly, by their geometrical and other indirect indications.

The task of multi spectral surveying consists of differentiating objects and determining their characteristics within these classes (species of trees in a forest, the composition of seeding, etc.), i.e., to solve problems which cannot be solved through regular surveys. Therefore the spectral zones for multi spectral surveying were chosen to distinguish objects within definite classes.

The spectral characteristics of terrestrial objects appear to be functions of limited spectra; therefore, as per Kotel'nikov's theorem, widely known in signal transmission theory, they can be reduced to a collection of discrete readings. This opens possibilities for creating a multi spectral system which would permit reduction of spectral characteristics, as a result of surveys in some spectral zones, and allow identification of objects within classes. By introducing a limitation for the degree of approximation and by selecting in a special way a new orthogonal basis of resolution, it is possible to significantly curtain the number of spectral zones necessary for identification [1]. The spectral sensitivity of various channels of this survey system must satisfy the orthonormal functions of the new basis. The spectral sensitivity of the aircraft multi spectral survey equipment was chosen with due regard /28 for the considerations expressed above and on the basis of an analysis of the departmental tasks of investigation. Consideration was given simultaneously to dealing with domestic and foreign materials with spectral brightness coefficients for different types of vegetation, agricultural cultivation, bodies of water differing in their physical composition, types of soil in dry and humid conditions, rocks, etc.

The effect of the atmosphere on the spectral brightness of objects was treated with the aid of B. B. Sobolev's formula [3], and the spectral optical width and scattering functions were adapted to meet the average state of atmospheric transperancy [2,4]. In addition consideration was given to the technical capabilities of the survey systems, the spectral characteristics of the existing radiation detectors, films, and characteristics of colored glass of industrial origin.

In order to carry out the experimental surveys, well known bands were selected, typical for the different natural and artificial landscapes of the Soviet Union, and of interest in the solution of scientific and applied scientific problems in geography and cartography, geology, hydrology and reclamation, and in the rural, forests and fishing industries. Surveys were carried out in forests, forest steppe, steppe, arid and desert zones, in montainous regions, in regions with a humid subtropical climate and with a dry climate. The surveys included both natural and man-made landscapes, including agricultural regions of green production and of farming by irrigation.

Regular landscape investigation and separate spectral metric measurements were made for the majority of objects photographed from the aircraft. They were made with a photometer, similar to the aircraft photometer, through a munber of zones and spectral characteristics. At the time of the flight of the Soyuz 12 spaceship, one of the bands was picked simultaneously from space and from the aircraft with identical multi spectral photographic equipment.

Visual study of the photographs shows that each object in its varied conditions has its own brightness distribution according to spectral zones. An analysis of this dispersion on the photographs makes it possible to /29
determine the stage of cotton vegetation, the degree of soil humidity, the turbidity of water in ponds, etc.

The material acquired by the aircraft laboratory, in conjunction with data from terrestrial observation and multi spectral photographs supplied by the crew of the Soyuz 12 spaceship, are being processed in the Institute for Space Research, Moscow State University and many other academic and departmental scientific and research institutions.

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